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**Lin**

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(54) **HYBRID BONDING WITH THROUGH SUBSTRATE VIA (TSV)**

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**H01L 21/768** (2006.01)

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CPC ..... **H01L 23/481** (2013.01); **H01L 21/76897** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01L 23/481; H01L 2924/06  
USPC ..... 257/774  
See application file for complete search history.

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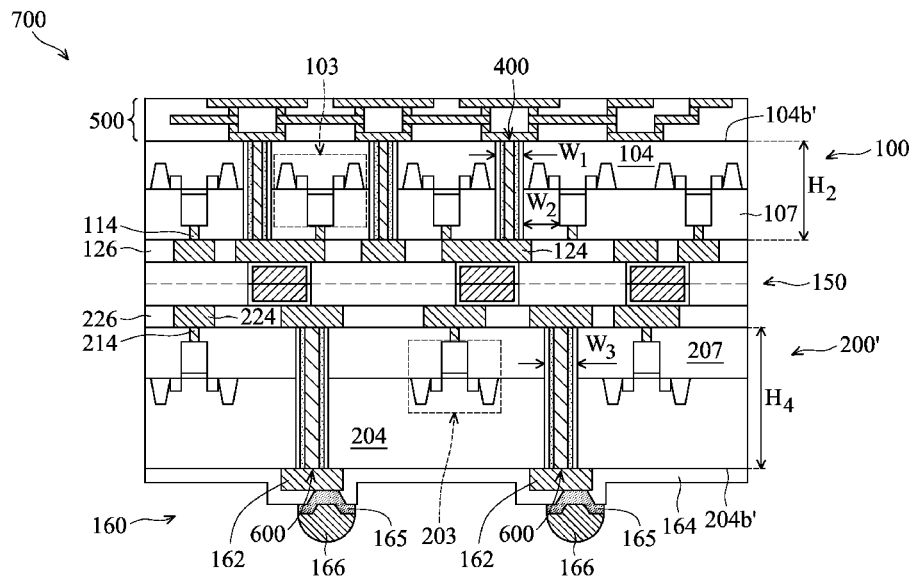
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(57) **ABSTRACT**

Embodiments of forming a semiconductor device structure are provided. The semiconductor device structure includes a first semiconductor wafer and a second semiconductor wafer bonded via a hybrid bonding structure, and the hybrid bonding structure includes a first conductive material embedded in a first polymer material and a second conductive material embedded in a second polymer material. The first conductive material is bonded to the second conductive material and the first polymer material is bonded to the second polymer material. The semiconductor device also includes at least one through silicon via (TSV) extending from a bottom surface of the first semiconductor wafer to a metallization structure of the first semiconductor wafer. The semiconductor device structure also includes an interconnect structure formed over the bottom surface of the first semiconductor wafer, and the interconnect structure is electrically connected to the metallization structure via the TSV.

**20 Claims, 8 Drawing Sheets**



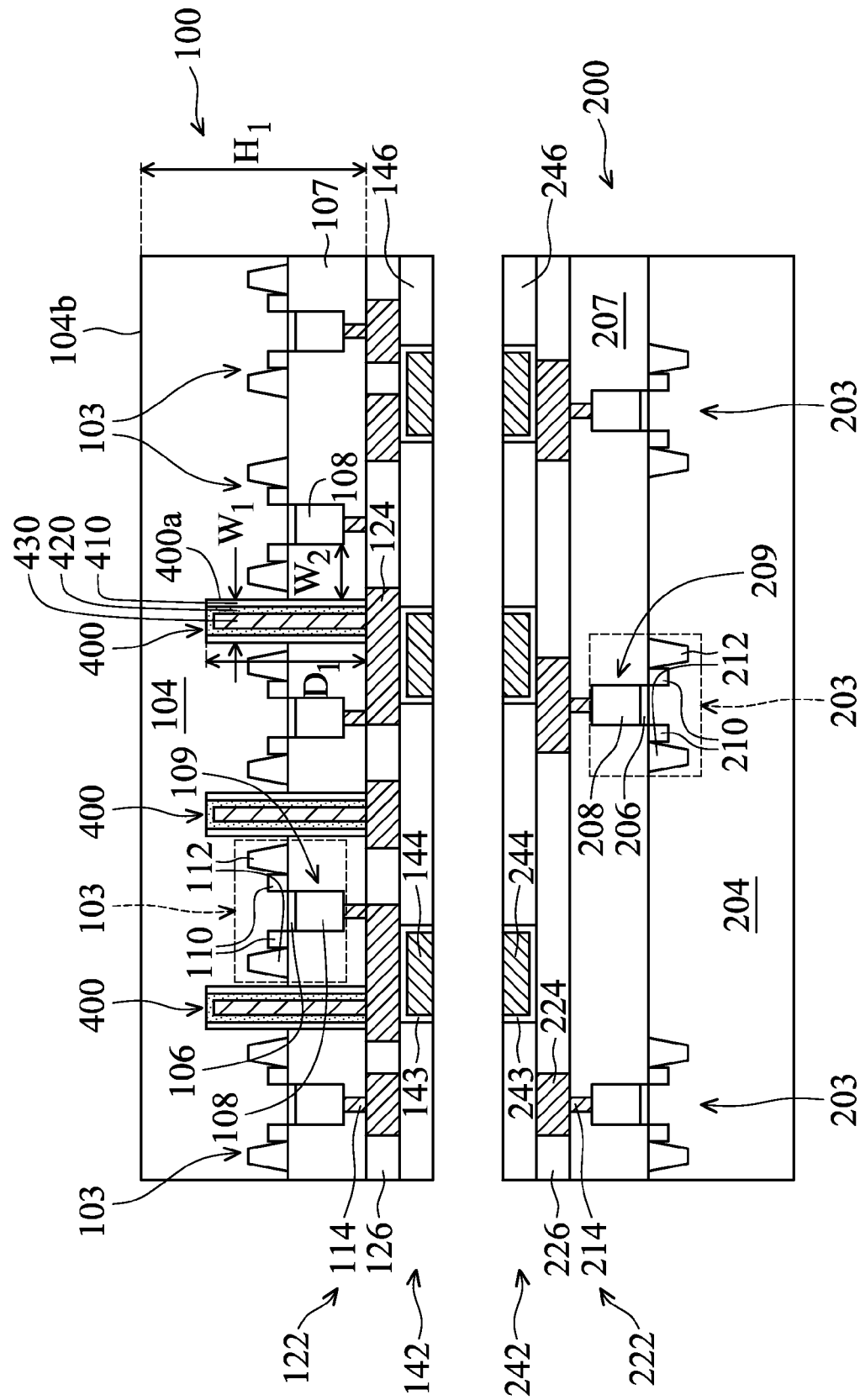


FIG. 1A

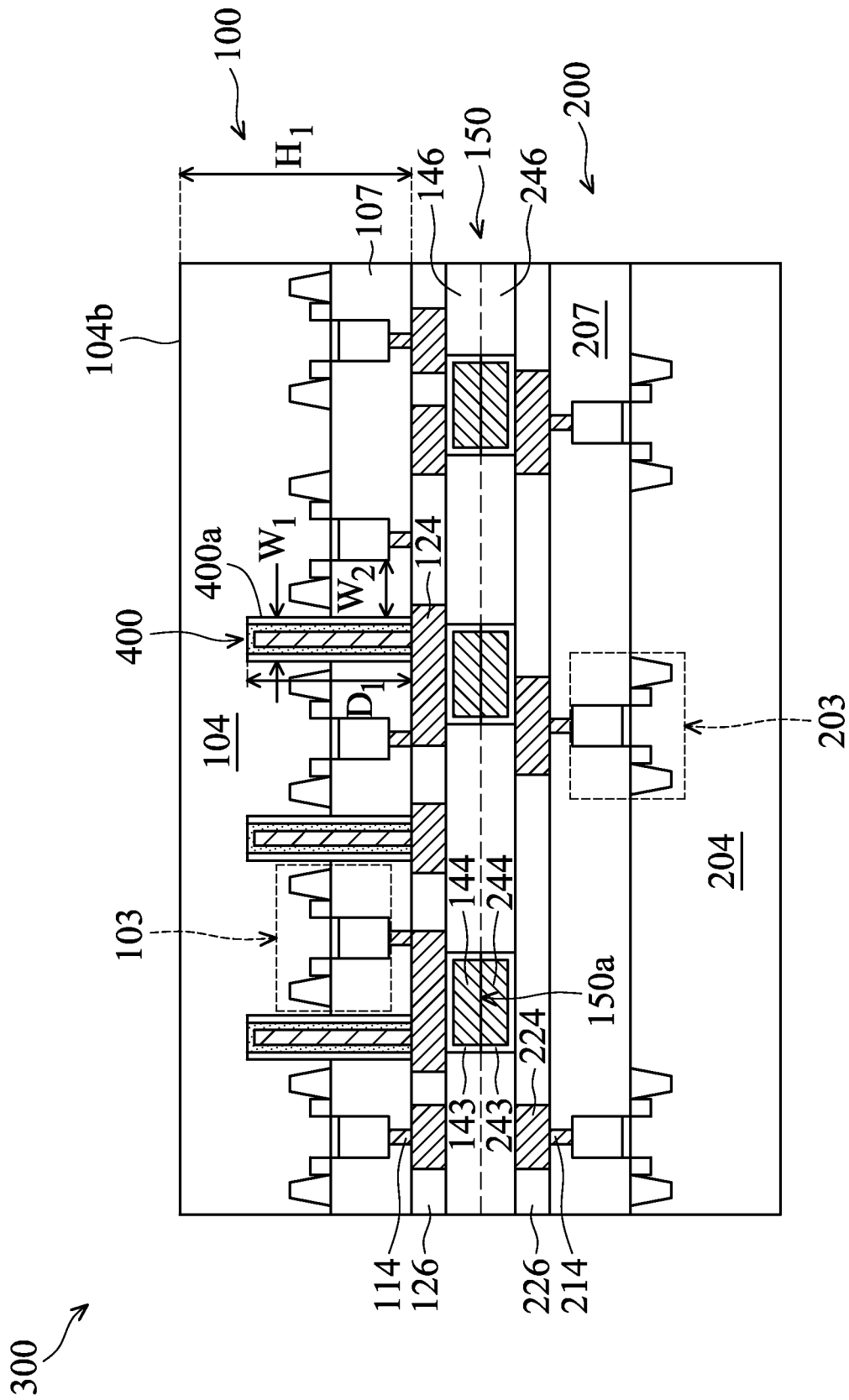


FIG. 1B

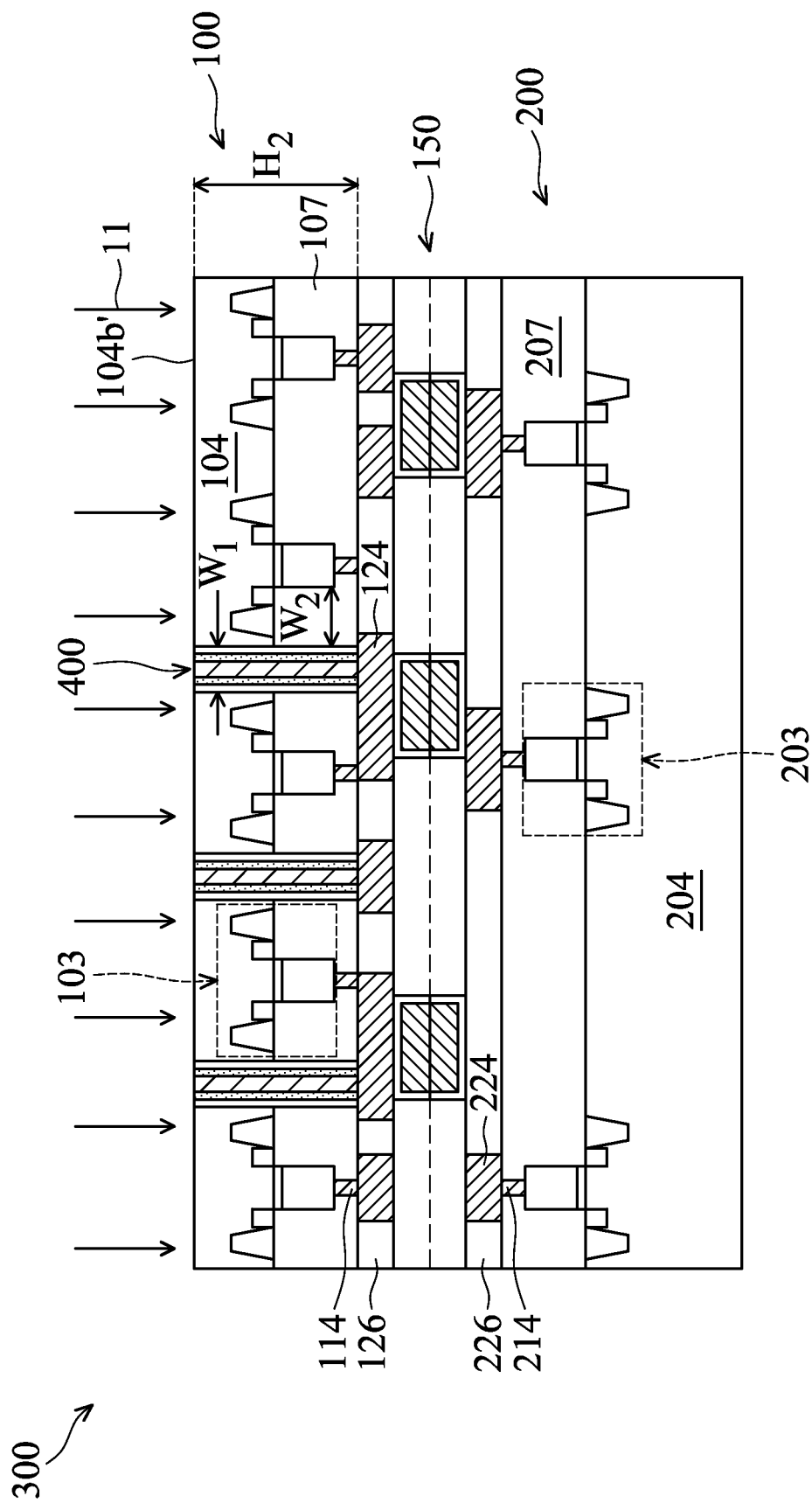


FIG. 1C

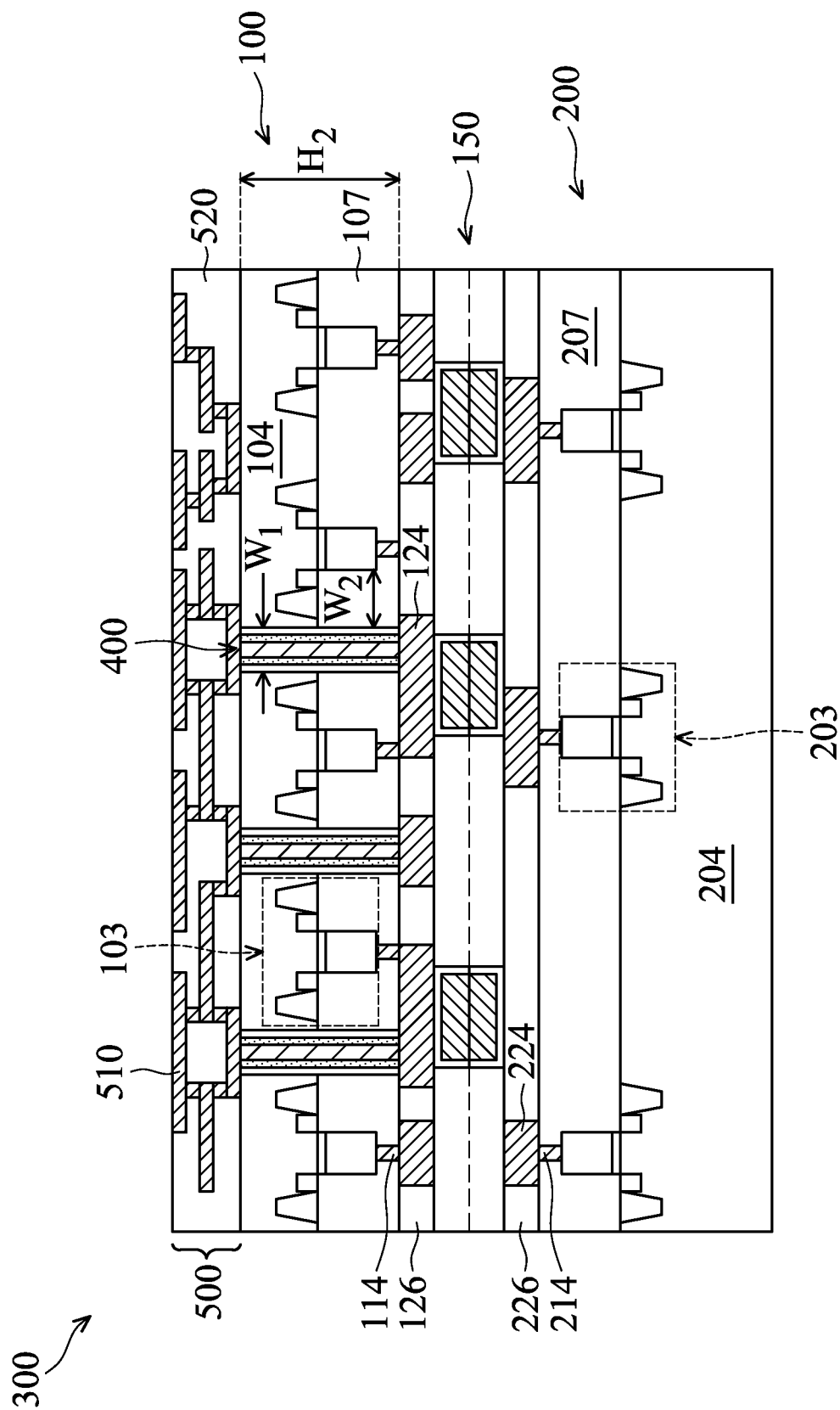


FIG. 1D

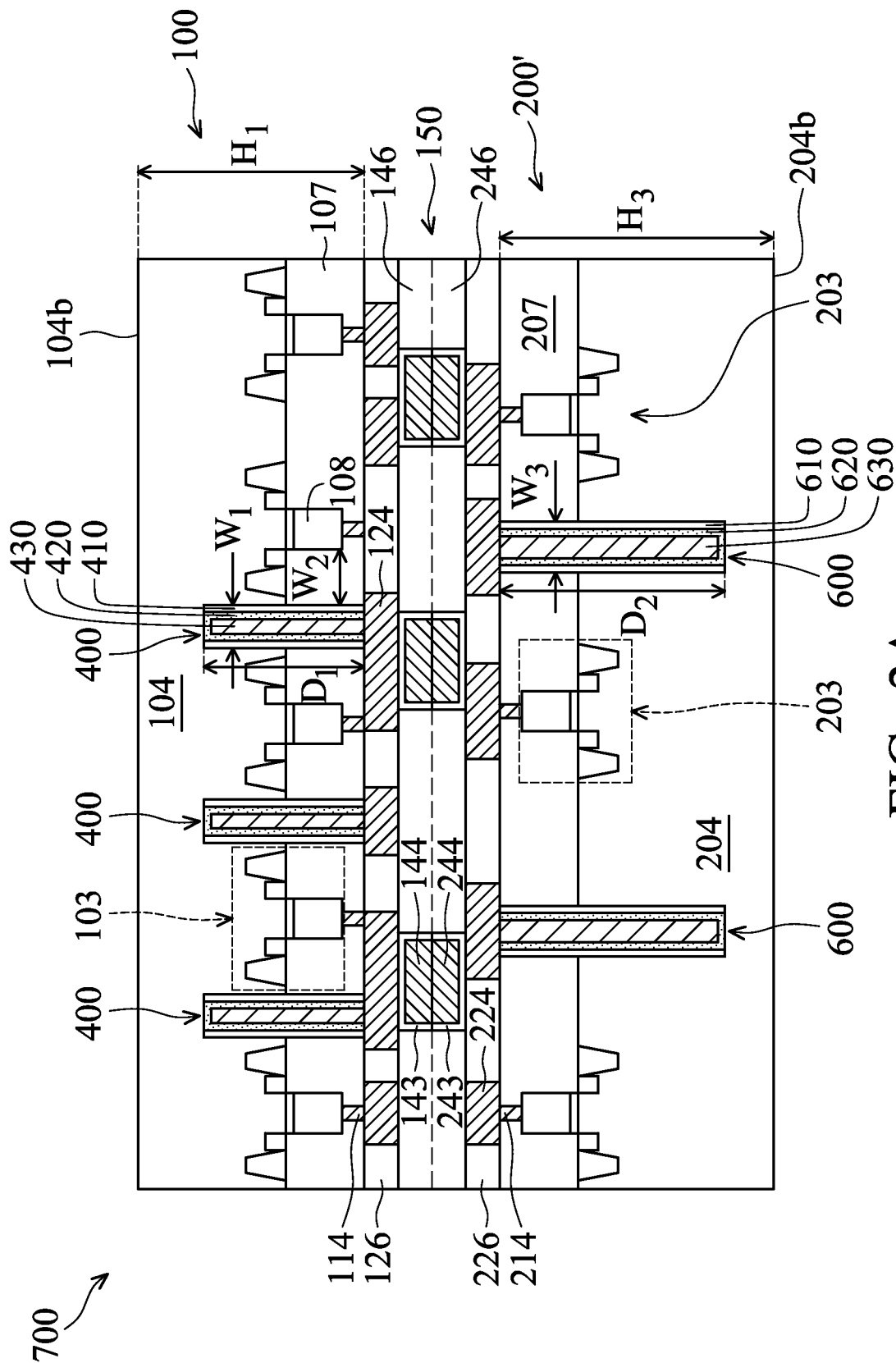
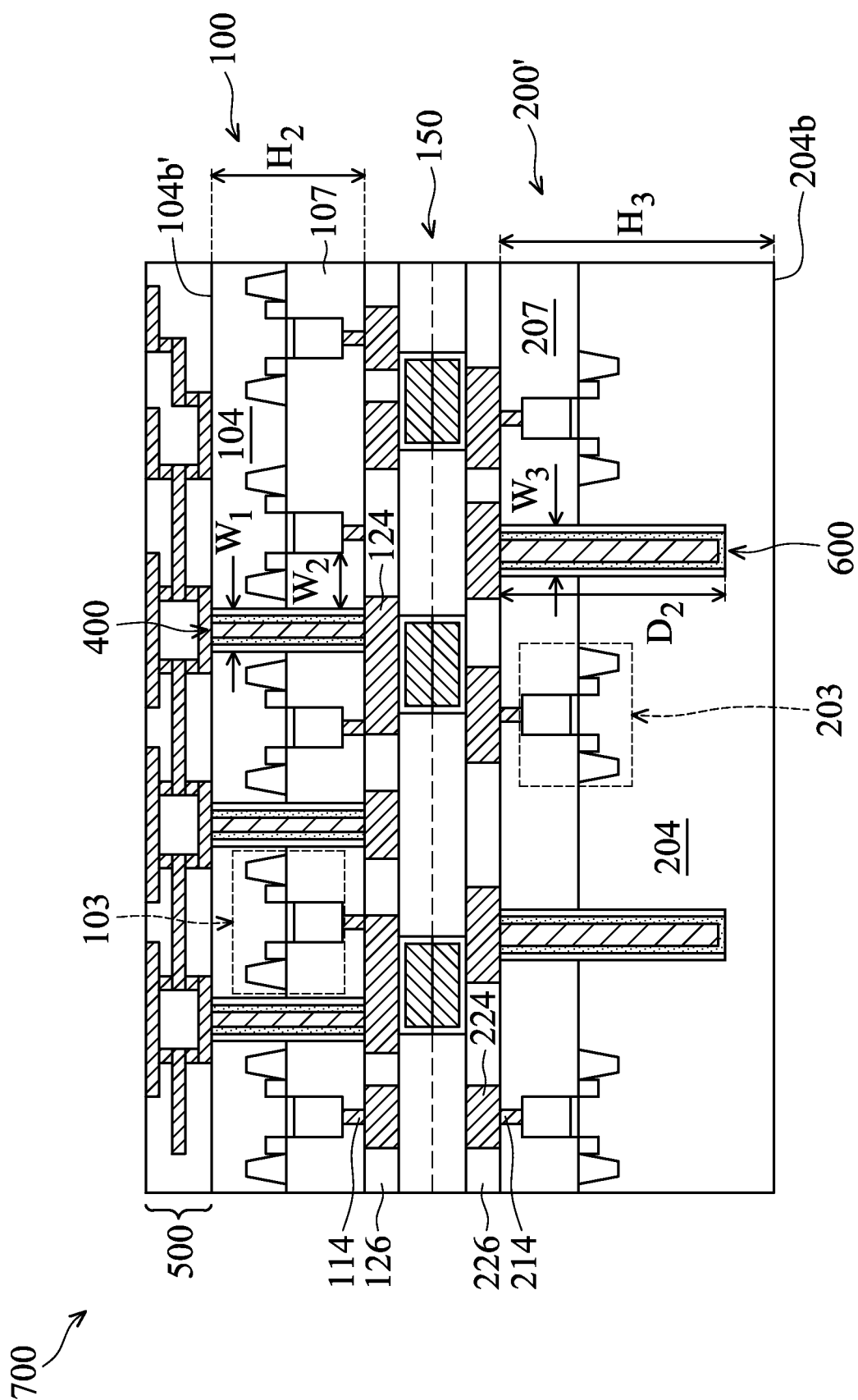


FIG. 2A



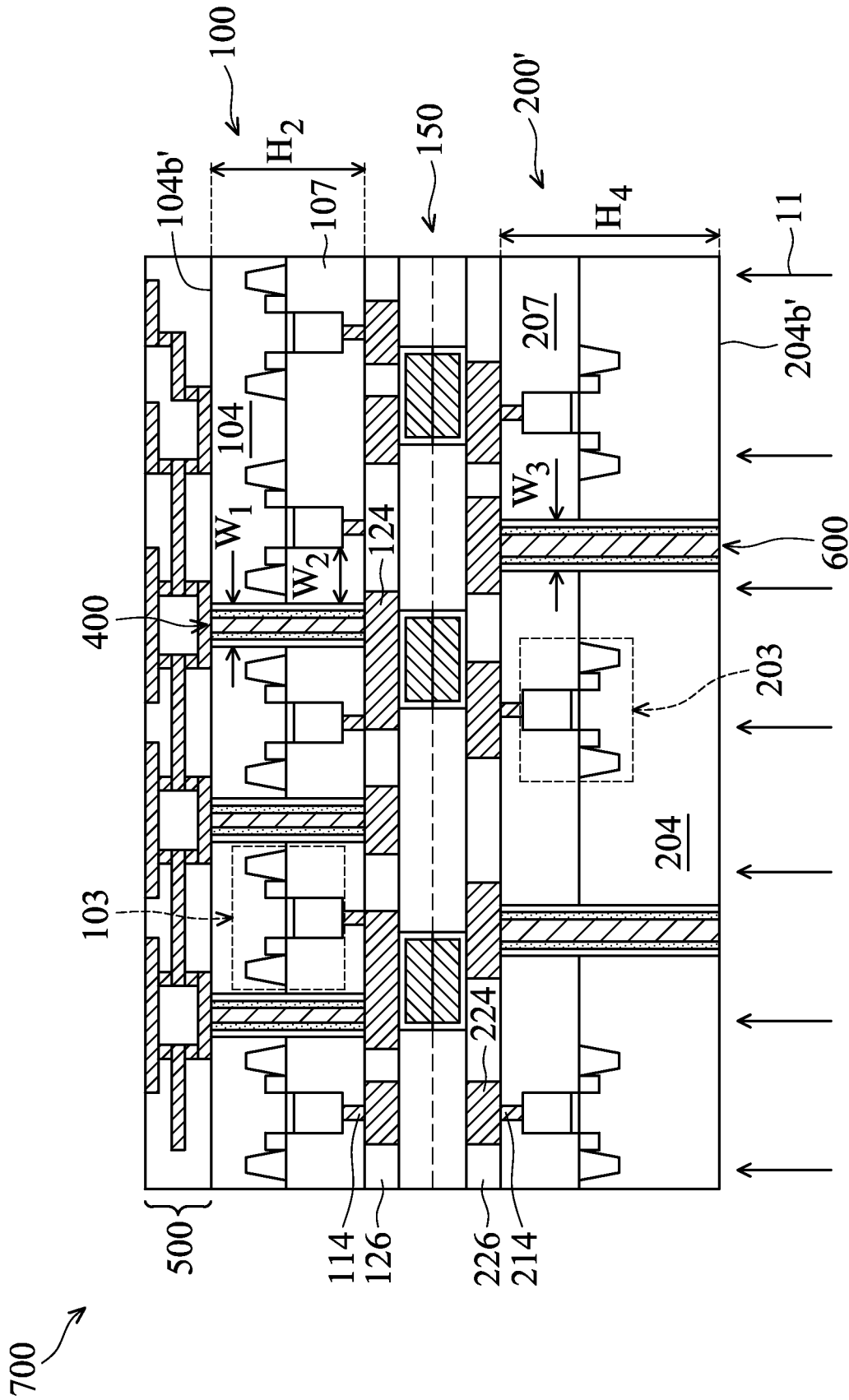
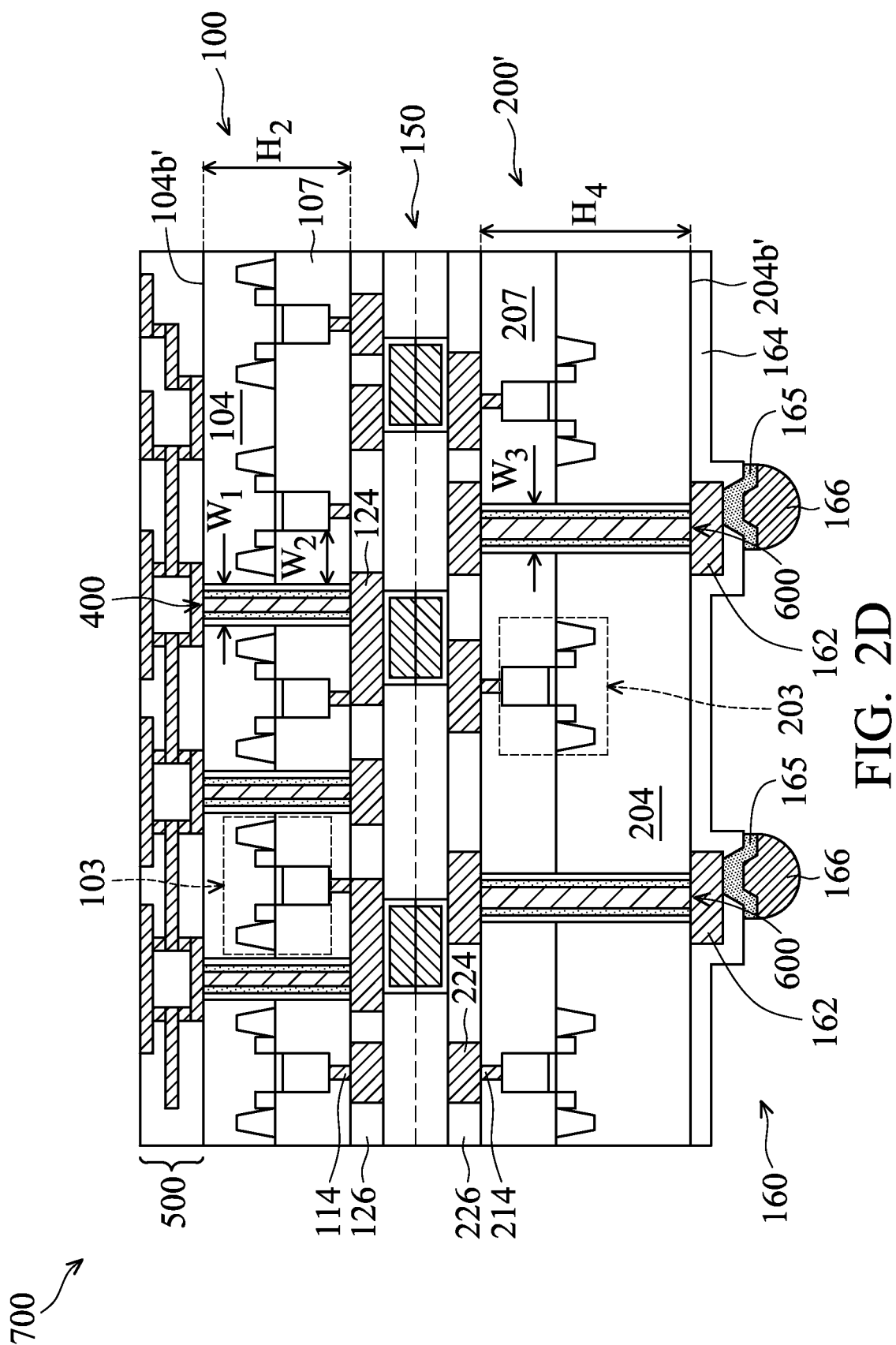


FIG. 2C





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## HYBRID BONDING WITH THROUGH SUBSTRATE VIA (TSV)

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to the following co-pending an commonly assigned patent applications: U.S. application Ser. No. 13/943,157, filed on Jul. 16, 2013 and entitled "Front-to-back bonding with through-substrate via (TSV)," U.S. application Ser. No. 13/943,245, filed on Jul. 16, 2013 and entitled "Mechanisms for forming three-dimensional integrated circuit (3DIC) stacking structure," U.S. application Ser. No. 13/943,401, filed on Jul. 16, 2013 and entitled "Hybrid bonding with through substrate via (TSV)," and U.S. application Ser. No. 14/488,017, filed on Sep. 16, 2014 and entitled "Hybrid bonding with through substrate via (TSV)."

### BACKGROUND

Semiconductor devices are used in a variety of electronic applications, such as personal computers, cell phones, digital cameras, and other electronic equipment. Semiconductor devices are typically fabricated by sequentially depositing insulating or dielectric layers, conductive layers, and semi-conductive layers of material over a semiconductor substrate, and patterning the various material layers using lithography to form circuit components and elements thereon. Many integrated circuits are typically manufactured on a single semiconductor wafer, and individual dies on the wafer are singulated by sawing between the integrated circuits along a scribe line. The individual dies are typically packaged separately, in multi-chip modules, or in other types of packaging, for example.

The semiconductor industry continues to improve the integration density of various electronic components (e.g., transistors, diodes, resistors, capacitors, etc.) by continual reductions in minimum feature size, which allow more components to be integrated into a given area. These smaller electronic components also require smaller packages that utilize less area than packages of the past, in some applications.

Three dimensional integrated circuits (3DICs) are a recent development in semiconductor packaging in which multiple semiconductor dies are stacked upon one another, such as package-on-package (PoP) and system-in-package (SiP) packaging techniques. Some 3DICs are prepared by placing dies over dies on a semiconductor wafer level. 3DICs provide improved integration density and other advantages, such as faster speeds and higher bandwidth, because of the decreased length of interconnects between the stacked dies, as examples. However, there are many challenges related to 3DICs.

### BRIEF DESCRIPTION OF THE DRAWING

For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGS. 1A-1D show cross-sectional representations of various stages of forming a semiconductor device, in accordance with some embodiments of the disclosure.

FIGS. 2A-2D show cross-sectional representations of various stages of forming a semiconductor device, in accordance with some embodiments of the disclosure.

### DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing

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different features of the disclosure. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. Moreover, the performance of a first process before a second process in the description that follows may include embodiments in which the second process is performed immediately after the first process, and may also include embodiments in which additional processes may be performed between the first and second processes. Various features may be arbitrarily drawn in different scales for the sake of simplicity and clarity. Furthermore, the formation of a first feature over or on a second feature in the description may include embodiments in which the first and second features are formed in direct or indirect contact.

FIGS. 1A-1D show cross-sectional representations of various stages of forming semiconductor devices in accordance with some embodiments. Referring to FIG. 1A, a cross-sectional representation of a portion of semiconductor wafer **100** and a portion of semiconductor wafer **200** are shown in accordance with some embodiments.

Semiconductor wafer **100** includes a semiconductor substrate **104**, which may be made of silicon or other semiconductor materials. Alternatively or additionally, semiconductor substrate **104** may include other elementary semiconductor materials such as germanium. In some embodiments, semiconductor substrate **104** is made of a compound semiconductor such as silicon carbide, gallium arsenic, indium arsenide, or indium phosphide. In some embodiments, semiconductor substrate **104** is made of an alloy semiconductor such as silicon germanium, silicon germanium carbide, gallium arsenic phosphide, or gallium indium phosphide. In some embodiments, semiconductor substrate **104** includes an epitaxial layer. For example, semiconductor substrate **104** has an epitaxial layer overlying a bulk semiconductor.

Referring to FIG. 1A, device regions **103** are formed in semiconductor wafer **100** in a front-end-of-line (FEOL) process in some embodiments. Each device regions **103** includes a gate structure **109** embedded in a dielectric layer **107**, source/drain regions **110**, and isolation structures **112**, such as shallow trench isolation (STI) structures. Gate structure **109** includes a gate dielectric layer **106**, a gate electrode **108**, and possibly spacers (not shown). Device regions **103** shown in FIG. 1A are merely examples, and other structures may be formed in device regions **103**.

Device regions **103** may form various N-type metal-oxide semiconductor (NMOS) and/or P-type metal-oxide semiconductor (PMOS) devices, such as transistors or memories, and the like, which are interconnected to perform one or more functions. Other devices, such as capacitors, resistors, diodes, photo-diodes, fuses, and the like may also be formed on substrate **104**.

As shown in FIG. 1A, through-substrate vias (TSVs) **400** are formed between two adjacent device regions **103**. TSVs **400** extend into substrate **104**. TSVs **400** are used to provide electrical connections and for heat dissipation for 3DICs. Although FIG. 1A shows four TSVs, the number of TSVs may be adjusted according to actual application.

Each TSVs **400** includes a liner **410**, a diffusion barrier layer **420**, and a conductive material **430** in accordance with some embodiments. Liner **410** is made of an insulating material, such as oxides or nitrides. Liner **410** may be formed by using a plasma enhanced chemical vapor deposition (PECVD) process or other applicable processes. Liner **410**

may be a single layer or multi-layers. In some embodiments, liner **410** has a thickness in a range from about 100 Å to about 5000 Å.

Diffusion Barrier layer **420** is made of Ta, TaN, Ti, TiN, or CoW. In some embodiments, diffusion barrier layer **420** is formed by a physically vapor deposition (PVD) process. Conductive material **430** is made of copper (Cu), copper alloy, aluminum (Al), aluminum alloys, or combinations thereof. Alternatively, other applicable materials may be used. In some embodiments, conductive material **430** is formed by plating.

With high aspect ratio, filling materials into the TSV opening becomes challenging. Voids may form in a TSV opening. In addition, due to insufficient sidewall coverage of liner **410** or diffusion barrier layer **420**, some extrusion or diffusion problems related to conductive via material **430** may occur. In contrast, as shown in FIG. 1A, TSVs **400** are designed to have a smaller depth  $D_1$  than height  $H_1$  of semiconductor wafer **100**. Therefore, the void problems and the extrusion or diffusion problems related to the conductive material **430** are resolved or greatly reduced.

In addition, width  $W_1$  of TSVs **400** is reduced along with a decrease of depth  $D_1$  of TSVs **400**. When distance  $W_2$  is smaller, a larger area of device regions **103** may be used. As a result, integrated intensity of the devices in device regions **103** is further improved.

In some embodiments, semiconductor wafer **100** has a height  $H_1$  from a bottom surface **104b** of semiconductor substrate **104** to a top surface of gate structure **109** in a range from about 1 μm to about 20 μm. In some embodiments, TSVs **400** have a width  $W_1$  in a range from about 0.025 μm to about 2 μm. In some embodiments, TSVs **400** have a depth  $D_1$  in a range from about 0.2 μm to about 10 μm. In some embodiments, TSVs **400** have an aspect ratio ( $D_1/W_1$ ) in a range from about 2 to about 15.

In addition, devices in the vicinity of the TSV suffer from serious performance degradation due to the stress induced by the TSV. A keep-out zone (KOZ) is used to define a region where no devices could be placed within. In some embodiments, keep-out zone (KOZ) is defined by a distance  $W_2$ , which is measured from a sidewall **400a** of TSV **400** to a nearest gate structure **209**. Since the depth  $D_1$  of TSVs **400** is made smaller, a smaller width  $W_1$  is achieved. Therefore, overall stress induced by TSVs **400** is reduced. In some embodiments, distance  $W_2$  is in a range from 0.01 μm to about 3 μm. In some embodiments, when width  $W_1$  of TSVs **400** is reduced to a range from about 2 μm to about 3 μm, the stress induced by TSV can almost be ignored.

As shown in FIG. 1A, a metallization structure **122** is formed over TSVs **400** and device regions **103** to individually connect to TSVs **400** and device regions **103**. In some embodiments, metallization structure **122** includes interconnect structure, such as contact plugs **114** and conductive features **124**. Conductive features **124** are embedded in an insulating material **126**. In some embodiments, insulating material **126** is made of silicon oxide. In some embodiments, insulating material **126** includes multiple dielectric layers of dielectric materials. Metallization structure **122** shown is merely for illustrative purposes. Metallization structure **122** may include other configurations and may include one or more conductive lines and via layers.

A bonding structure **142** is formed over metallization structure **122**. Bonding structure **142** includes a conductive material **144** embedded in a polymer material **146**. Conductive material **144** is contact pad (or bond pad) formed on a top surface of semiconductor wafer **100**. Conductive features **124** are connected to conductive material **144**. Conductive mate-

rial **144** may be made of conductive materials, such as copper (Cu), copper alloy, aluminum (Al), aluminum alloy, or combinations thereof. Other applicable materials may be used as conductive material **144**.

In some embodiments, if conductive material **144** is made of a metal, such as copper, which is easy to diffuse, a diffusion barrier layer **143** is needed. Diffusion barrier layer **143** may be made of silicon nitride (SiN), silicon oxynitride (SiON), titanium nitride (TiN), tantalum nitride (TaN), or aluminum nitride (AlN). In some embodiments, conductive material **144** is made of copper, and diffusion barrier layer **143** is made of Ti, TiN, Ta, TaN, Ta/TaN, CoP or CoW. In some embodiments, diffusion barrier layer **143** has a thickness in a range from about 5 Å to about 1000 Å.

In some embodiments, polymer material **146** is benzocyclobutene (BCB) polymer, polyimide (PI), or polybenzoxazole (PBO). In some embodiments, polymer material **146** is made of benzocyclobutene (BCB) polymer and is applied to metallization structure **122** by spin coating. Since benzocyclobutene polymer is a soft material, it can tolerate more stress resulting from the TSV formed in the subsequent processes, compared to other dielectric materials such as silicon dioxide.

As shown in FIG. 1A, semiconductor wafer **200** is similar to semiconductor wafer **100**. Semiconductor wafer **200** includes a substrate **204** and device regions **203**. Substrate **204** is similar to substrate **104**. Device regions **203** are similar to device regions **103** and include a gate structure **209**, source/drain regions **210**, and isolation structures **212**. Gate structure **209** is similar to gate structure **109** and includes a gate dielectric layer **206**, a gate electrode **208**, and possibly spacers (not shown). Gate dielectric layer **206** is similar to gate dielectric layer **106**, and gate electrode **208** is similar to gate electrode **108**. In addition, source/drain regions **210** in devices **203** are similar to source/drain regions **110**, and isolation structures **212** in devices **203** are similar to isolation structures **112**.

Semiconductor wafer **200** further includes a metallization structure **222** and a bonding structure **242**. Metallization structure **222** is similar to metallization structure **122** and includes a contact plug **214** embedded in a dielectric layer **207** and conductive features **224** embedded in an insulating material **226**. Contact plug **214** is similar to contact plug **114**, and dielectric layer **207** is similar to dielectric layer **107**. Conductive features **224** are similar to conductive features **124**, and insulating material **226** is similar to insulating material **126**. Bonding structure **242** is similar to bonding structure **142** and includes a conductive material **244** and a polymer material **246**. Conductive material **244** is similar to conductive material **144**, and polymer material **246** is similar to polymer material **146**. Metallization structure **222** may further include a diffusion barrier layer **243** which is similar to diffusion barrier layer **143**.

Before semiconductor wafer **100** is bonded to semiconductor **200**, semiconductor wafers **100** and **200** are aligned, such that conductive material **144** on semiconductor wafer **100** can be bonded to conductive material **244** on semiconductor wafer **200** and polymer material **146** on semiconductor wafer **100** can be bonded to polymer material **246** on semiconductor wafer **200**. In some embodiments, the alignment of semiconductor wafers **100** and **200** may be achieved by using an optical sensing method.

Referring to FIG. 1B, after the alignment is performed, semiconductor wafers **100** and **200** are bonded together by hybrid bonding to form a 3DIC stacking structure **300** (die stack). Semiconductor wafers **100** and **200** are hybrid bonded together by the application of pressure and heat. In some embodiments, during hybrid bonding, stacking structure **300**

is heated to a temperature in a range from about 100° C. to about 200° C., such that polymer materials **146** and **246** become a non-confined viscous liquid and are reflowed. By reflowing polymer materials **146** and **246**, voids therein are eliminated.

Afterwards, stacking structure **300** is further heated to a higher temperature in a range from about 220° C. to about 380° C., such that conductive materials **144** and **244** are interconnected by thermocompression bonding and polymer materials **146** and **246** are fully cured. In some embodiments, the pressure for hybrid bonding is in a range from about 0.7 bar to about 10 bar. The hybrid bonding process may be performed in an inert environment, such as an environment filled with inert gas including N<sub>2</sub>, Ar, He, or combinations thereof.

As shown in FIG. 1B, hybrid bonding involves at least two types of bondings, including metal-to-metal bonding and non-metal-to-non-metal bonding. As shown in FIG. 1B, a hybrid bonding structure **150** is formed between semiconductor wafers **100** and **200**. Hybrid bonding structure **150** includes conductive materials **144** and **244** bonded by metal-to-metal bonding and polymer materials **146** and **246** bonded by non-metal-to-non-metal bonding. As shown in FIG. 1B, bonding structure **150** has a metallic bonding interface **150a** between conductive materials **144** and **244** but may not have a clear non-metallic interface between polymer materials **146** and **246** due to the reflowing process.

Compared to hybrid bonding involving other dielectric layers, semiconductor wafers **100** and **200** are bonded through polymer materials **146** and **246**. Since the bonding of polymer materials **146** and **246** involves the reflowing of polymer materials **146** and **246**, voids in polymer materials **146** and **246** are eliminated and bonding strength of semiconductor wafers **100** and **200** is improved.

Referring to FIG. 1C, after hybrid bonding, stacking structure **300** is put on a tape (not shown) and a thinning process **11** is performed on a bottom surface **104b** of semiconductor wafer **100**. After thinning process **11**, TSVs **400** are exposed. Thinning process **11** may include a grinding operation and a polishing operation (such as chemical mechanical polishing (CMP)). After thinning process **11**, a wet etching operation is performed to remove the defects formed on bottom surface **104b'** of semiconductor wafer **100**. In some embodiments, bottom portion of diffusion barrier layer **420** is removed to expose conductive material **430** by thinning process **11**. Therefore, after thinning process **11**, height  $H_2$  is smaller than depth  $D_1$ . In some embodiments, TSVs **400** have an aspect ratio ( $H_2/W_2$ ) in a range from about 2 to about 15. In some other embodiments, height  $H_2$  is equal to depth  $D_1$ . After thinning process **11**, semiconductor wafer **100** has a height  $H_2$  from bottom surface **104b** of semiconductor substrate **104** to a top surface of gate structure **109** in a range from about 0.2  $\mu$ m to about 10  $\mu$ m. Height  $H_2$  is smaller than height  $H_1$ . In some embodiments, height  $H_2$  is in a range from about 0.01 to about 0.99 of height  $H_1$ .

If thinning process **11** is performed before semiconductor wafers **100** and **200** are bonded, the thin semiconductor wafer **100** is easy to break during subsequent processes. However, if semiconductor wafers **100** and **200** are bonded firstly, as shown in FIG. 1C, such bonding enables the thinning of semiconductor wafer **100**. As a result, semiconductor wafer **100** could be thinned to a relatively smaller height  $H_2$  compared to semiconductor wafer **100** is directly thinned before bonding.

Referring to FIG. 1D, an interconnect structure **500** is formed on bottom surface **104b** of semiconductor wafer **100**. Interconnect structure **500** is electrically connected to con-

ductive features **124** over substrate **104** via TSVs **400**. Interconnect structure **500** includes conductive features **510**, such as conductive lines, vias, or conductive pads, formed in an insulating material **520**. The metal routing of the conductive features shown in FIG. 1D is merely an example. Alternatively, other metal routing designs of conductive features may be used according to actual application.

After forming interconnect structure **500**, one or more redistribution layers (RDLs) (not shown) may be formed over interconnect structure **500**. For example, redistribution layers (RDLs) are embedded in a passivation layer. Interconnect structure **500**, redistribution layers (RDLs) and TSVs **400** provide electrical interconnection. In addition, since TSVs **400** have a relatively low resistance, RC delay is reduced.

In addition, other processes may also be performed to 3DIC stacking structure **300**, and 3DIC stacking structure **300** may be diced to form individual chips afterwards.

FIGS. 2A-2D show cross-sectional schematic representations of various stages of forming a semiconductor device in accordance with some embodiments. Referring to FIG. 2A, a 3DIC stacking structure **700** is formed by bonding semiconductor wafers **100** and **200**. As shown in FIG. 2A, semiconductor wafer **200'** is almost the same with semiconductor wafer **200** except that TSVs **600** are formed in semiconductor wafer **200'**. In some embodiments, TSVs **400** have a diameter different from that of TSVs **600**. In some embodiments, the formation of TSVs **600** involves additional patterning and etching processes. In some embodiments, number of the TSVs **400** is larger than that of TSVs **600**. In some other embodiments, number of the TSVs **400** is smaller than that of TSVs **600**.

As shown in FIG. 2A, each TSVs **600** includes liner **610**, which is similar to liner **410**, diffusion barrier layer **620**, which is similar to diffusion layer **420**, and conductive material **630**, which is similar to conductive material **430**. TSVs **600** extend to metal pad **224** of semiconductor wafer **200**.

Because semiconductor wafer **200** will be thinned later to expose TSVs **600**, TSVs **600** do not extend through the whole substrate **204** of semiconductor wafer **200**. Therefore, TSVs **600** are designed to have a depth  $D_2$  which is smaller than original height  $H_3$  of semiconductor wafer **100**.

In some embodiments, semiconductor wafer **200** has a height  $H_3$  from a bottom surface **204b** of semiconductor substrate **204** to a top surface of gate structure **209** in a range from about 17  $\mu$ m to about 100  $\mu$ m. In some embodiments, TSVs **600** have a width  $W_3$  in a range from about 0.3  $\mu$ m to about 10  $\mu$ m. In some embodiments, TSVs **600** have a depth  $D_2$  in a range from about 15  $\mu$ m to about 100  $\mu$ m. In some embodiments, TSVs **600** have an aspect ratio ( $D_2/W_3$ ) in a range from about 5 to about 15. In some embodiments, depth  $D_1$  is the same as depth  $D_2$ . In some other embodiments, depth  $D_1$  is different with depth  $D_2$ .

Referring to FIG. 2B, semiconductor wafer **100** is thinned to height  $H_2$  and interconnect structure **500** is formed on bottom surface **104b** of semiconductor wafer **100**. Interconnect structure **500** is similar to interconnect structure **500** in FIG. 1D, and detail description of interconnect structure **500'** will not be repeated again for brevity.

Referring to FIG. 2C, after forming interconnect structure **500**, stacking structure **700** is put on a tape and a thinning process **11** is performed on a bottom surface **204b** of semiconductor wafer **200**. After thinning process **11**, TSVs **600** are exposed. Thinning process **11** is described above and will not be repeated for brevity. After thinning process **11**, semiconductor wafer **100** has a height  $H_4$  from bottom surface **204b'** of semiconductor substrate **204** to a top surface of gate structure **109** in a range from about 15  $\mu$ m to about 100  $\mu$ m. Height  $H_4$

is smaller than height  $H_3$ . In some embodiments, height  $H_4$  is equal to or smaller than depth  $D_2$ .

Referring to FIG. 2D, redistribution (RDL) structure **160** is formed on bottom surface **104b** of substrate **104**. RDL structure **160** include a metal pad **162** formed in a passivation layer **164**. Metal pad **162** is electrically connected to exposed TSVs **600**. Metal pad **162** is made of conductive materials with low resistivity, such as copper (Cu), aluminum (Al), Cu alloys, Al alloys, or other applicable materials. Although FIG. 2D only shows one RDL structure **160**, more than one RDL structures may be formed.

An under bump metallization (UBM) layer **165** is formed on metal pad **162**, and conductive element **166** (such as solder ball) is formed over UBM layer **165**. UBM layer **165** may contain an adhesion layer and/or a wetting layer. In some embodiments, UBM layer **165** is made of titanium (Ti), titanium nitride (TiN), tantalum nitride (TaN), tantalum (Ta), or the like. In some embodiments, UBM layer **165** further includes a copper seed layer. In some embodiments, conductive element **166** is made of conductive materials with low resistivity, such as solder or solder alloy. Exemplary elements included in the solder alloy include Sn, Pb, Ag, Cu, Ni, Bi or combinations thereof.

Interconnect structure **500'** is electrically connected to another package (not shown) on the backside of semiconductor wafer **200** via TSVs **600**, RDL structure **160** and conductive element **166**.

TSVs **400** and **600** individually provide different functions. Semiconductor wafer **100** is electrically connected to another package structure (not shown) via interconnect structure **500** and TSVs **400**. Semiconductor wafer **200** is electrically connected to another package structure (not shown) via interconnect structure **500'** and TSVs **600**. TSVs **400** and **600** provide a fast conductive path to connect semiconductor wafer **100**, semiconductor wafer **200**, and/or other package structures, without the formation of complicated metal routings.

Embodiments of mechanisms for forming a die stack are provided. Two semiconductor wafers are bonded together by hybrid bonding with metal-to-metal bonding and polymer-to-polymer bonding to form the die stack. TSVs are formed before the two semiconductor wafers are bonded. One or both of the semiconductor wafers are thinned to expose the TSVs after the semiconductor wafers are bonded. The bonded semiconductor wafers provides extra strength to reduce the risk of wafer breaking during a thinning process. In addition, polymer-to-polymer bonding is strong, and the polymer material is soft to provide a cushion to absorb the stress resulting from the TSVs.

In some embodiments, a semiconductor device structure is provided. The semiconductor device includes a first semiconductor wafer and a second semiconductor wafer bonded via a hybrid bonding structure, and the hybrid bonding structure includes a first conductive material embedded in a first polymer material; and a second conductive material embedded in a second polymer material, and the first conductive material is bonded to the second conductive material and the first polymer material is bonded to the second polymer material. The semiconductor device also includes at least one through silicon via (TSV) extending from a bottom surface of the first semiconductor wafer to a metallization structure of the first semiconductor wafer. The semiconductor device structure also includes an interconnect structure formed over the bottom surface of the first semiconductor wafer, and the interconnect structure is electrically connected to the metallization structure via the TSV.

In some embodiments, a semiconductor device structure is provided. The semiconductor device includes a first semiconductor wafer and a second semiconductor wafer bonded via a hybrid bonding structure. The semiconductor device also includes at least one first TSV extending from a bottom surface of the first semiconductor wafer to a metallization structure of the first semiconductor wafer. The semiconductor device further includes at least one second TSV extending from a bottom surface of the second semiconductor wafer to a metallization structure of the second semiconductor wafer; and a width of the first TSV is different with that of the second TSV.

In some embodiments, a method for forming a semiconductor device structure is provided. The method includes providing a first semiconductor wafer and a second semiconductor wafer, and at least one through substrate via (TSV) is formed in the first semiconductor wafer, and the TSV extends from the bottom surface of the first semiconductor wafer to a metallization structure of the first semiconductor wafer. The method also includes hybrid bonding the first semiconductor wafer and the second semiconductor wafer. The method further includes thinning the first semiconductor wafer from a bottom surface of the first semiconductor wafer to expose the TSV.

Although embodiments of the present disclosure and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims. For example, it will be readily understood by those skilled in the art that many of the features, functions, processes, and materials described herein may be varied while remaining within the scope of the present disclosure. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present disclosure. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

What is claimed is:

1. A semiconductor device structure, comprising:

a first semiconductor wafer bonded to a second semiconductor wafer via a hybrid bonding structure, wherein the hybrid bonding structure comprises:

a first conductive material embedded in a first polymer material; and

a second conductive material embedded in a second polymer material, wherein the first conductive material is bonded to the second conductive material and the first polymer material of the first semiconductor wafer is bonded to the second polymer material of the second semiconductor wafer; and

at least one through substrate via (TSV) extending from a bottom surface of the first semiconductor wafer to a metallization structure of the first semiconductor wafer; and

- an interconnect structure formed over the bottom surface of the first semiconductor wafer, wherein the interconnect structure is electrically connected to the metallization structure via the TSV.
2. The semiconductor device structure as claimed in claim 1, further comprising:
- a transistor formed in the first semiconductor wafer, wherein the transistor is electrically connected to the metallization structure.
3. The semiconductor device structure as claimed in claim 1, wherein the interconnect structure comprises conductive features formed in an insulating material.
4. The semiconductor device structure as claimed in claim 1, wherein the first semiconductor wafer has a first height, and the second semiconductor wafer has a second height, and the first height is smaller than the second height.
5. The semiconductor device structure as claimed in claim 1, wherein the TSV has an aspect ratio in a range from about 2 to about 15.
6. The semiconductor device structure as claimed in claim 1, wherein the TSV further comprises:
- a liner formed on a sidewall of a TSV opening;
  - a diffusion barrier layer conformally formed on the liner; and
  - a conductive material formed on the diffusion barrier layer.
7. The semiconductor device structure as claimed in claim 1, further comprising:
- at least one second TSV extending from a bottom surface of the second semiconductor wafer to a metallization structure of the second semiconductor wafer.
8. The semiconductor device structure as claimed in claim 1, wherein the first polymer material and the second polymer material are respectively benzocyclobutene (BCB) polymer, polyimide (PI), or polybenzoxazole (PBO).
9. The semiconductor device structure as claimed in claim 1, wherein a keep-out zone (KOZ) defines a region where no active device is placed within, and a distance defined by the KOZ is measured from the sidewall of the TSV to an active device is in a range from about 0.01  $\mu\text{m}$  to about 3  $\mu\text{m}$ .
10. A semiconductor device structure, comprising:
- a first semiconductor wafer bonded to a second semiconductor wafer via a hybrid bonding structure, wherein the hybrid bonding structure comprises a first polymer material of the first semiconductor wafer is bonded to a second polymer material of the second semiconductor wafer;
- at least one first TSV extending from a bottom surface of the first semiconductor wafer to a first metallization structure of the first semiconductor wafer; and
- at least one second TSV extending from a bottom surface of the second semiconductor wafer to a second metalli-

- zation structure of the second semiconductor wafer, wherein a width of the first TSV is different from that of the second TSV.
11. The semiconductor device structure as claimed in claim 10, further comprising:
- a transistor formed in the first semiconductor wafer, wherein the transistor is electrically connected to the first metallization structure.
12. The semiconductor device structure as claimed in claim 10, wherein the hybrid bonding structure comprises a first conductive material embedded in a first polymer material and a second conductive material embedded in a second polymer material.
13. The semiconductor device structure as claimed in claim 12, wherein the first polymer material and the second polymer material are respectively benzocyclobutene (BCB) polymer, polyimide (PI), or polybenzoxazole (PBO).
14. The semiconductor device structure as claimed in claim 10, further comprising:
- an interconnect structure formed over the bottom surface of the first semiconductor wafer, wherein the first TSV is electrical connected to the interconnect structure.
15. The semiconductor device structure as claimed in claim 14, wherein the interconnect structure is electrically connected to the first metallization structure via the first TSV.
16. The semiconductor device structure as claimed in claim 10, further comprising:
- a redistribution (RDL) structure formed over the bottom surface of the second semiconductor wafer, wherein the second TSV is electrically connected to the RDL structure.
17. The semiconductor device structure as claimed in claim 10, wherein the first semiconductor wafer has a first height, and the second semiconductor wafer has a second height, and the first height is smaller than the second height.
18. The semiconductor device structure as claimed in claim 10, wherein the first TSV has an aspect ratio in a range from about 2 to about 15.
19. The semiconductor device structure as claimed in claim 10, wherein the first TSV further comprises:
- a liner formed on a sidewall of a TSV opening;
  - a diffusion barrier layer conformally formed on the liner; and
  - a conductive material formed on the diffusion barrier layer.
20. The semiconductor device structure as claimed in claim 10, wherein a keep-out zone (KOZ) defines a region where no active device is placed within, and a distance defined by the KOZ is measured from the sidewall of the TSV to an active device is in a range from about 0.01  $\mu\text{m}$  to about 3  $\mu\text{m}$ .

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